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COMPLETE SPECIFICATION.

Improvements in or relating to Gas Turbine Installations.

We, RICHARDSONS, WESTGARTH & CO., LIMITED, a British Company, of Northumberland, Engine Works, Wallsend, Northumberland, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to gas turbine installations and is particularly concerned with electricity-generating installations having a gas turbine which drives an alternator.

Most generating installations do not work at peak load all the time, and it has therefore been proposed to use the power which is available during off-peak hours to drive compressors which fill a storage chamber or reservoir with compressed air. This compressed air can then be used during peak load operation as charging air for the gas turbine or turbines. The storage chamber may well be an air-tight underground cavern, while the charging compressors can be driven by one or more electric motors supplied with current from an external source, or, alternatively, by an alternator which is run as a motor during off-peak hours. An alternator or generator which is run as a motor at certain times is hereinafter referred to as an alternator/motor or generator/motor.

The system outlined above has a number of advantages, but one difficulty which is encountered is that the pressure of the air delivered from the storage chamber during peak load operation varies over quite a wide range. For example, the pressure of the air within the chamber could be about 50 atmospheres at the beginning of a peak load cycle and only about 20 atmospheres at the end of it. This presents a problem in the design of the turbine which cannot be made to operate with the same output when it is supplied with charging air at 20 atmospheres pressure as when it is supplied with charging air at 50 atmospheres pressure. One possible solution is to throttle the air supply from the storage chamber so that its pressure is reduced to about 20 atmospheres at all times, and to design the turbine for that pressure. That however is wasteful of the energy put into the gas during compression and results also in a lower-pressure turbine which limits the maximum power output of the installation.

The aim of the present invention is to devise an arrangement which constitutes a better solution the problem outlined above, and according to the invention the inlet side of the gas turbine is connected to the storage reservoir or chamber for compressed air through one or more main compressors, the overall pressure ratio of said main compressor, or compressors, if there are more than one, being substantially less than that of the turbine.

The advantage of this arrangement is that the air supply from the storage chamber, instead of being delivered direct to the turbine, is first passed through a compressor where its pressure is brought up to a value approaching that for which the turbine has been designed. In general, the turbine will be designed for the maximum pressure of air available from the storage chamber, so that the effective pressure rise to which the

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air from the chamber is subjected by the compressor will gradually increase from a very low value at the beginning of the peak load cycle to, say, 30 atmospheres at the end of the cycle when the pressure of the air from the chamber has dropped from 50 atmospheres to 20 atmospheres. By this means the pressure of the air at the turbine inlet is maintained approximately at the design value and full flow through the turbine is ensured.

It is to be noted that, in operation of the installation, the air supply from the storage chamber to the compressor will be appreciably above atmospheric pressure. As a result, the pressure ratio of the compressor will always be substantially less than the pressure ratio of the turbine. In this respect the installation differs from a conventional arrangement having a charging compressor for the gas turbine, as in the latter case the pressure ratio of the compressor is always greater than that of the turbine.

The manner in which the air supply from the storage chamber is compressed to a variable extent by the compressor or compressors can take a number of different forms. In one particular arrangement the compressor is driven by an auxiliary turbine in parallel with the main turbine, the power output of the auxiliary turbine being controlled by a throttle valve which throttles the air supplied to it from the storage chamber. Alternatively, a constant speed compressor driven by the main turbine can be used, the variable pressure rise required being obtained by the provision of a valve-controlled by-pass passage which returns variable amounts of air from the delivery side of the compressor back to the inlet side. The best arrangement, however, involves the use of a constant-speed axial-flow or centrifugal compressor which is driven by the main turbine and which is provided with means for varying the stagger of the stator blades so as to vary the pressure rise of the compressor. This particular arrangement is thermodynamically attractive and does not increase the cost of the installation to any great extent.

In order that the invention and certain of its subsidiary features may be thoroughly understood, a specific installation in accordance with it will now be described, by way of example, with reference to the accompanying drawing, in which:

Figure 1 is a diagrammatic view of the installation; and

Figure 2 is an enlarged sectional view of part of the installation shown in Figure 1.

The installation shown in Figure 1 comprises a gas turbine 10 arranged to drive an alternator/motor 12 through a shaft 14 which also carries a low-pressure compressor 16 and an intermediate-pressure compressor 18. The end of the shaft 14 remote from the alternator drives a pair of high-pressure compressors 20 and 22 through gearing 24.

An underground air-tight storage cavern 26 is connected by a passage 28 to the inlet side of each of the high-pressure compressors 20 and 22, and is further connected by a passage 30 to the delivery side of the compressor 22. The delivery side of the low-pressure compressor 16 is connected to the inlet side of the intermediate-pressure compressor 18 through a passage which contains an intercooler 32, and in a similar way the delivery side of the compressor 18 is connected to the inlet side of the high-pressure compressor 22 through a passage 34 containing an intercooler 35.

The delivery side of the turbine 10 has an outlet passage 36 which leads direct to atmosphere. However, a branch 38 from this passage leads back to the inlet side of the high-pressure compressor 20 through an intercooler 40. Similarly, a passage 42 connecting the delivery side of the compressor 20 to the inlet side of the turbine 10 has a branch 44 which leads to the inlet side of an auxiliary compressor 46 arranged to be driven through gearing 48 by a motor 50. The passage 34 leading from the intermediate-pressure compressor 18 also has a branch 52 which is connected to the inlet side of a second auxiliary compressor 54 driven through gearing 56 by a motor 58.

The installation operates as follows:

During such times as the alternator/motor 12 is being used as a generator, the turbine 10 is supplied with charging air from the storage chamber 26 through the passage 28 and the parallel-connected high-pressure compressors 20 and 22. Each of these two compressors has means for varying the stagger of the stator blades, and the blades are accordingly adjusted as required so that, not withstanding the gradual drop in pressure within the storage chamber 26, the charging air supplied to the inlet of the turbine 10 remains substantially at the value for which the turbine has been designed. Air entering the turbine is heated by combustion with oil-fuel in combustion chambers 60 located within the turbine casing, and the exhaust air and combustion gases from the turbine are passed direct to atmosphere through the outlet passage 36.

It will be noted that, besides driving the alternator 12 and the compressors 20 and 22, the turbine also drives the compressors 16 and 18 during generating periods despite the fact that they are not required at those times. The amount of work absorbed by the compressors 16 and 18 can in fact be kept down to a very low level by throttling the inlet to the compressor 16 and starting up the motor 58 so that air is continuously

withdrawn from the two compressors 16 and 18 by the auxiliary compressor 54. This arrangement is much to be preferred to the provision of shaft couplings which, in this instance, would have to be able to transmit high power and yet be readily coupled-up or uncoupled as desired.

During off-peak hours the installation is used to recharge the storage chamber 26. The alternator 12 is then run as a motor using off-peak electricity which is often available at a cheaper rate. The branch passage 52 is closed and the motor 58 shut down so that air entering the low-pressure compressor 16 now passes through the intermediate-pressure compressor 18 to the high-pressure compressor 22. From here the compressed air is passed into the storage chamber 26 through the passage 30.

In order to avoid the use of an expensive and complicated coupling between the alternator/motor 12 and the turbine 10, the turbine remains coupled to the alternator/motor during the air charging periods of operation. As with the compressors 16 and 18 during generating periods, however, the auxiliary compressor 46 driven by the motor 50 is used to reduce to a low level the power absorbed by the turbine and the high-pressure compressor 20. In addition, air exhausted from the turbine is not passed to atmosphere through the outlet 36 but is instead re-circulated back to the inlet side of the compressor 20 through the by-pass passage 38 and the intercooler 40. Alternatively, the inlet to the compressor 20 and the outlet 36 from the turbine can be opened to atmosphere and fuel burned in the combustion chambers 60. This in effect converts the power loss into a fuel loss—which is generally not disadvantageous. An advantage of these arrangements is that the turbine can be used as a starter motor for the installation by supplying air to the turbine inlet from the storage chamber 26. This results in a considerable saving in the cost of auxiliary electrical gear.

As already indicated, it is undesirable for the air supply to the turbine 10 to be throttled during generating periods. If, therefore, it is desired to run the installation on part-load operation, the inlet to the compressor 16 can be unthrottled, the passage 52 closed, and the compressors 16, 18 and 22 used to supply part of the requirements of the turbine 10. In this way something like $\frac{3}{4}$ load is achieved with only half the normal full load air consumption from the storage chamber 26. In other words, it is preferable for the compressors 16 and 18 to be kept running during part-load operation so that the power which is not required for generating purposes is used to reduce the demand on the chamber 26 for compressed air.

A modification to the installation shown in the drawing consists in providing a clutch or similar connection between the turbine 10 and the high-pressure compressors 20 and 22 so that the latter can be cut out of operation. This can be useful on those occasions when the storage chamber 26 is out of use, as it permits the turbine to be kept in operation using the low-pressure compressor 16 and the intermediate-pressure compressor 18 as a source of charging air for the turbine. In order that the turbine shall be matched to the compressors under this condition, the design pressure ratio of the compressors 16 and 18 is made substantially equal to the ratio of the normal turbine/compressor flows.

A further modification of the installation involves the use of an auxiliary "storage" chamber (not shown) which is exhausted to, say, 1/20th of an atmosphere by the compressors 16 and 18 during generating periods. The turbine 10 and the idle high pressure compressor 20 are then connected to this evacuated chamber during charging periods so that windage losses, which are roughly proportional to the pressure of the incoming air, are reduced to a lower level. This arrangement dispenses with the auxiliary compressor 46. If desired, the turbine can be connected to the auxiliary chamber through the compressor 20 so that the air in the turbine is at an even lower pressure than that in the auxiliary chamber.

In the interests of compactness, it is advantageous for the casings of the two compressors 16 and 18 to be brought as close together as possible. This enables the intercooler 32 to be made an integral part of the two compressor casings as shown in Figure 2.

WHAT WE CLAIM IS:—

1. A gas turbine installation in which the inlet side of the turbine is connected to a storage reservoir for compressed air through one or more main compressors, the overall pressure ratio of said main compressor, or compressors, if there are more than one, being substantially less than that of the turbine.

2. A gas turbine installation according to claim 1, in which the main compressor, or each main compressor, is driven by the turbine and is provided with means for varying the stagger of the stator blades so as to vary its pressure ratio.

3. A gas turbine installation according to claim 1, in which the main compressor is driven by the turbine and is provided with a valve-controlled by-pass passage for returning variable amounts of air from the delivery side of the main compressor back to the inlet side in order to vary its pressure ratio.

4. A gas turbine installation according to claim 1, in which the main compresssor is driven by an auxiliary turbine provided with means for varying its speed in order to vary the pressure ratio of the main compressor.

5. A gas turbine installation according to any preceding claim, in which the turbine is mechanically coupled to an electrical generator/motor and to one or more reservoir-recharging compressors the delivery of which is connected to the storage reservoir so as to deliver compressed air to the latter when the generator/motor is being used as a motor.

6. A gas turbine installation according to claim 5, in which means are provided for reducing the pressure within the reservoir-recharging compressor or compressors when the turbine is driving the generator/motor.

7. A gas turbine installation according to claim 6, in which the said pressure-reducing means comprise a throttle valve on the inlet side of the reservoir-recharging compressor or compressors, and a motor-driven auxiliary compressor having its inlet side connected to the delivery side of the reservoir-recharging compressor or compressors.

8. A gas turbine installation according to claim 6, in which a comparatively large chamber is connected to the inlet side of the reservoir-recharging compressor or compressors to be exhausted when the turbine is driving the generator/motor.

9. A gas turbine installation according to any one of claims 5—8, in which the delivery of the reservoir-recharging compressor or compressors, is connected to the storage reservoir through the main compressor or one of the main compressors.

10. A gas turbine installation according to any one of claims 5—9, in which a motor-driven auxiliary compressor is connected on its inlet side to the turbine so as to reduce the power absorbed by the turbine when it is being driven by the generator/motor.

11. A gas turbine installation according to claim 10, in which a by-pass passage is provided for recirculating exhaust air from the turbine back to the inlet side of the main compressor, or one of the main compressors, when the turbine is being driven by the generator/motor.

12. A gas turbine installation according to claim 11, in which an intercooler is provided in said turbine-exhaust-recirculating by-pass passage.

13. A gas turbine installation according to claim 2 or any claim appendent thereto, in which a clutch is provided between the turbine and the main compressor or compressors.

14. A gas turbine installation according to claim 5 having two series-connected reservoir-recharging compressors, in which the casings of the two compressors are juxtaposed and include an intercooler forming an integral part of the casings.

15. A gas turbine installation substantially as described with reference to the accompanying drawing.

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Fig.1.

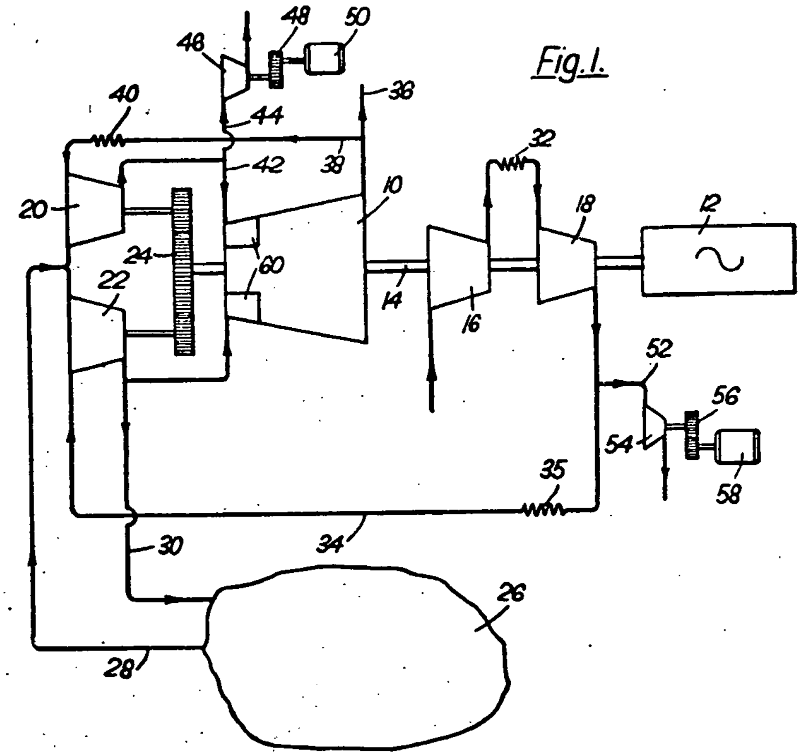
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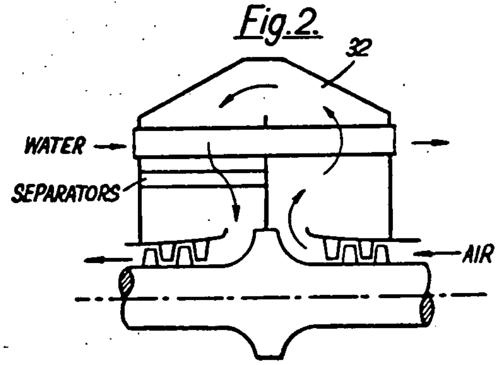
Fig.2.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